LABORATORY INVESTIGATION OF STONE MATRIX ASPHALT USING BAGASSE FIBER

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

BY

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DEPARTMENT OF CIVIL ENGINEERING

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UNDER THE GUIDANCE OF

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Certificate

This is to certify that the Project Report entitled "**LABORATORY INVESTIGATIONS OF STONE MATRIX ASPHALT USING BAGASSE FIBRE** " submitted by **Mr.RAJENDRA SOREN** in partial fulfilment of the requirements for the award of Bachelor Of Technology Degree in Civil Engineering at National Institute Of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.To the best of my knowledge, the matter embodied in this Project Report has not been submitted to any other University/Institute for the award of any Degree or Diploma

Date: 14/05/2012

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ABSTRACT

Stone matrix asphalt (SMA) is a gap graded mix which contains a high concentration of coarse aggregate which are held together by a rich matrix of mineral filler, fiber or polymer as stabilizers in a thick asphalt film. SMA uses a structural basis of stone to stone contact in the mix by utilizing high concentration of coarse aggregates and thus provides an efficient network for load distribution. The rich mortar binder provides durability. Cellulose fibers, mineral fibers or polymers are added to SMA mixtures as stabilizing agent to prevent drain downof the mix. These structural characteristics makes SMA to maximize deformation resistance or rutting, provides durability and longevity in the service life of the pavements.

In this project an attempt is being made to study the engineering behavior ofmixtures of stone matrix asphalt with a non-conventional natural waste fiber, namely sugarcane fiber which is a waste product after extraction of juice from sugarcane fiber. To achieve this various samples of SMA mixtures with and without fibers with different binder content were prepared. Marshall Properties were used to determine the optimum binder content .Thereafter other properties such as the drain down characteristics, static indirect tensile strength parameters were determined. The MORTH specifies t addition of only 0.3% fiber, use of which has shown significant improvement in the stability, drain down and indirect tensile strength characteristics to meet the design standards.

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CHAPTER 1
INTRODUCTION

INTRODUCTION

1.1 GENERAL

In early 1960 European asphalt industry was in urgent need of a surface course to resist rutting, abrasion and distresses due to heavy traffic and studded tires. As a result SMA was developed. It was first developed in Germany and due to its superior performances SMA was eventually included as a standardized mixture class in their pavement specifications. Due to its higher rut resistance and durability it is being extensively used in other European countries for over two decades. As a result of this considerable success achieved by SMA in Europe, various other countries including India have started using SMA or researching on its implementation and viability for their pavements.

Various studies reveals that use of SMA for surfacing road pavements is expected to significantly increase the durability and rut-resistance of the mixes. SMA is a gap graded mixture containing 70-80% coarse aggregate of total aggregate mass, 6-7% of binder, 8-12% of filler, and about 0.3-0.5% of fiber or modifier .Due to high content of coarse aggregate there is better stone to stone contact and better interlocking which serves as the structural basis of SMA, Since aggregates do not deform as much as asphalt binder under load, this stone-on-stone contact greatly reduces rutting. Thus use of high coarse aggregate provide better rut resistance and provides skid resistance .Due to high content of bitumen it fills the voids between the aggregates affectively and binds them together , thus contributing to its durability from premature cracking and raveling . Apotential problem associated with SMA is drainage and bleeding. Bleeding is caused due to difficulty in obtaining the required compaction. High bitumen content causes drainage, and as storage and placement temperatures cannot be lowered it remain a major problem associated with SMA .Therefore stabilizing additives such as fibers , rubber and polymers are being used to stiffen the matrix thereby reducing the drain down and bleeding significantly .

The different types of stabilizing agents commonly used in SMA are generally expensive hence there exist a need to obtain analternative, lower-cost stabilizers that will essentiallyserve the same objective, in a similar way as obtained by using other commonly used stabilizing additives. Hence here we have tried to use an unconventional natural cellulose fiber, namely the sugarcane fiber. Sugarcane fiber contains some amount of cellulose which is required for controlling then drain down.

1.2 ADVANTAGES

- High stability against permanent deformation (rutting) and high wear resistance .[1]
- Slow aging and durability to premature cracking of the asphalt .[2]
- Longer service-life
- SMA has a higher macro-texture than dense-graded pavements for better friction.[2]
- Reduced spray, reduced hydroplaning and reduced noise.

- Good low temperature performance
- Broad range of application

Even though SMA has a higher cost than conventional dense mixes, approximately 20 to 25 percent, the advantages of longer life (decreased rutting and increased durability), reduced splash and spray, and reduced surface noise may compensate for the added cost [3]. The higher cost of SMA is attributed to the addition ofmineral filler, fibers, modified binders, and possible higher asphalt contents.

1.3 OBJECTIVES

- The main objective of this project is to replace conventional fiberwith a non conventionalnatural waste fiber such as bagasse fiber which is obtained after extraction of juice from sugarcane, and to study its effect on various properties of SMA.
- To compare the Marshall properties of SMA samples with varying binder Concentrations and to obtain optimum binder content with the help of Marshall Test data
- To study the drain down characteristics of the SMA mixes prepared at OBC
- To compare its other engineering properties such as static indirect tensile test at OBC.
- To find suitability of Bagasse fiber for use in SMA

1.4 RESEARCH APPROACH

The objective of this study was accomplished by designing various SMA mixtures using different binder content and a specific fiber content. The binder used was of 60/70 penetration value. The fiber percentage as laid down by as per MORTH standards was 0.3% [4]. Here we have tried to use 0.3% fiber as we are intended to see the response of SMA with minimum fiber content as per MORTHstandards. The mineral filler used was cement as it is most widely and easily available .Various Marshall specimens of SMA with and without fibers were prepared and various tests conducted on it to obtain the engineering properties .The tests were conducted to obtain the various Marshall properties from which the optimum binder content were determined at 0.4% air voids. It was also used to determine the drain down characteristics and static indirect tensile strength. Finally these engineering properties were compared to obtain the results, hence making the purpose of the study complete.

1.5 TESTS

The tests conducted were as follows:

1.5.1 Marshall Test

Marshall Tests were conducted on various SMA specimens with and without fibers to obtain various Marshall Properties such as stability,flow, air voids, unit weight and various others properties. The results were used to determine the optimum binder content (OBC) with which further test were to be conducted. It is found from previous research that the stability value is low at lower binder content, then increases with increase in binder, attains maximum and finally reduces with further increase in binder.

1.5.2 Drain down test

Drain down test was conducted to obtain the drain down percentage in SMA samples at OBC with and without fibers and the results were compared. It was found that the drain down significantly reduces with the use of fibers.

1.5.3 Static Indirect Tensile Test

The static indirect tensile test was used to determine the tensile strength of SMA samples with fiber under static load at the OBC. Its tensile strength characteristics at varying temperature were also studied to obtain the effect of temperature on tensile strength of SMA.

CHAPTER 2
LITERATURE REVIEW

LITERATURE REVIEW

2.1 GENERAL

A plethora of research had been done and is continuing for the development and improvements in SMA. A brief review of literature studied and applied for the synthesis of this project is being described below.

Ever sincethe development of SMA in Germany in mid 1960's and its success in other European countries, many countries worldwide have taken the philosophy of SMA. It was standardized by many countries worldwide and became a part of the transportation authorities for the countries, including India. In India, the Flexible Pavement Committee (FPC) decided in its meeting held on 22nd April, 2006 that a specification be developed for SMA suited to Indian conditions [4].

2.2 DIFFERENCE BETWEEN SMA AND CONVENTIONAL MIXES

SMA is successfully used by many countries in the world as highly rut resistant bituminous course, both for binder (intermediate) and wearing course. The major difference between conventional mixes and SMA is in its structural skeleton .The SMA has high percent about 70-80 percent of coarse aggregate in the mix .This increases the interlocking of the aggregates and provides better stone to stone contact which serves as load carrying mechanism in SMA and hence provides better rut resistance and durability .On the other hand, conventional mixes contain about 40-60 percent coarse aggregate. They does have stone to stone contact, but it often means the larger grains essentially float in a matrix composed of smaller particles, filler and asphalt content .The stability of the mix is primarily controlled by the cohesion and internal friction of the matrix which supports the coarse aggregates [5] .It can be followed from diagram of the grain size distribution of the mixes given below.

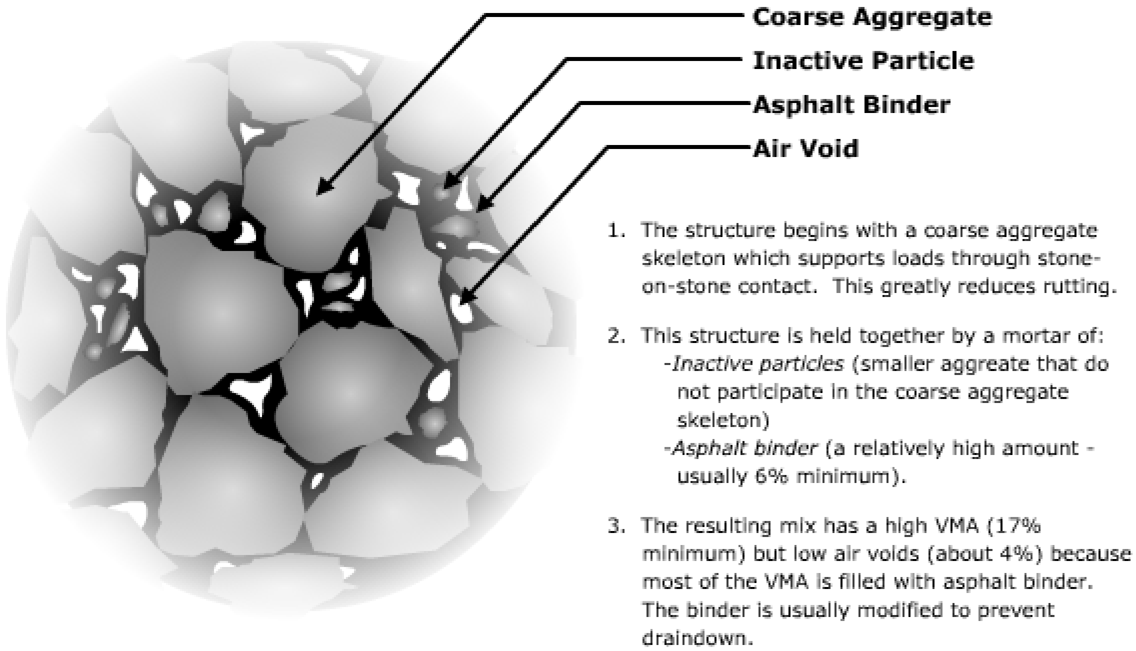

Figure 2.1: SMA Structure

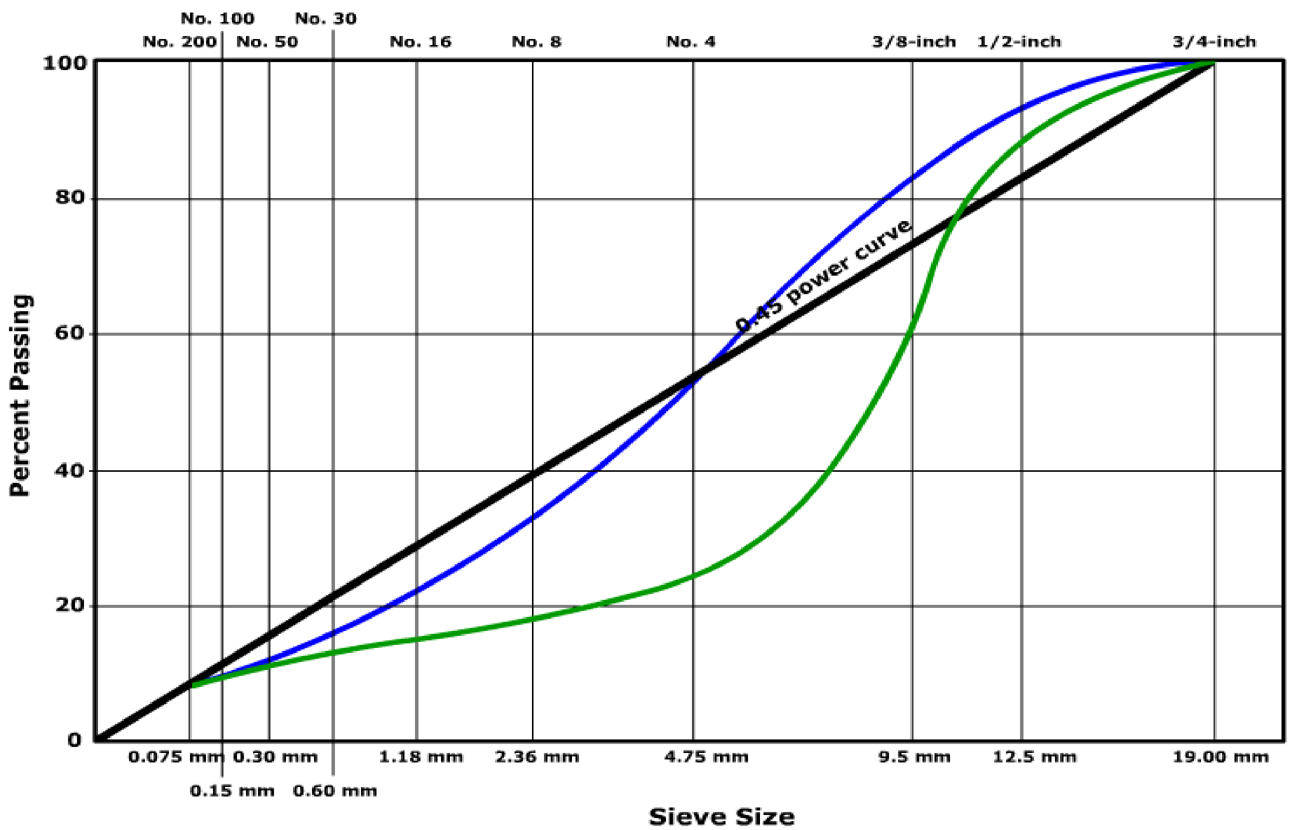

Figure 2.2: Typical SMA and Dense-Graded HMA Aggregate Gradations

The second difference lies in the binder content which lies between 5-6 percent for conventional mixes. Below this the mix becomes highly unstable. Above this percent will lead to abrupt drop of stability because the binder fills all the available voids and the extra binder makes the aggregates to float in binder matrix. The SMA uses very high percent of binder > 6.5 percent which is attributed to filling of more amount of voids present in it, due to high coarse aggregate skeleton. The high bitumen content contributes to the longevity of the pavements.

The third difference is the use of stabilizing additives in SMA which is attributed to the filling up of large no of voids in SMA so as to reduce the drain down due to presence of high bitumen content. On the contrary, there is no stabilizing agent in conventional mixes since the bitumen content is moderate, which only serves the purpose of filling the moderate amount of voids and binding the aggregates [6]. Diagrammatic representation of conventional mixes and SMA is given below.

Figure 2.3: SMA Surface

Figure 2.4: Dense-Graded HMA Close up

Figure 2.5: Dense-Graded HMA (left) vs. SMA (right).
(SMA is a bit more shiny from the extra asphalt binder)

2.3 MATERIAL CHARACTERISTICS

2.3.1 Mineral aggregates

The aggregate structure and quality in SMA is an important factor that makes this mixture resistant to rutting. Therefore, the stability of the aggregate structure is crucial to ensure the proper design of a mixture. A Washington State Department of Transportation study recommends the following quality of aggregates [7]:

(1) Highly cubic shapeand rough texture to resist rutting and movements,
(2) Hardness which can resist fracturingunder heavy traffic loads,
(3) High resistance to polishing, and
(4) High resistance to abrasion

Different types of aggregates have been used in SMA such as sand stone,limestone,novaculite,blast furnace slag basically depending on the local availability of the materials. Mohammad et al. studied the SMA performances using three different aggregates and was found out that sandstone produces the least permanent deformation which is the most important factor for rutting resistance. It was also concluded that SMA production with lime stone is least desirable due to its high permanent deformation.

Marco Pasetto and **Nicola Baldo** studied the effect of SMA using steel slag as aggregates and found out that it effectively satisfies the requisites for acceptance in the road sector technical standards. It also showed higher mechanical characteristics than those of the corresponding asphalts with full natural aggregate.

Research by **Y. F. Qiu** and **K. M. Lum** found that aggregate gradation is an important factor which helps in better understanding of its effect on the load-carrying capacity of an asphalt mixture basically the stone matrix asphalt (SMA) [9]. In this research it was found out that the coarse aggregate stone-to-stone contact was developed when the volume of coarse aggregate was in the range of 95–105% of the rodded unit weight. The test results indicated that the SMA mixtures having better stone-to-stone contact exhibited excellent rutting characteristics which areessentialcharacteristics of aggregate gradation.

Thus we can see that aggregate quality has greater impact on the SMA performance but use of different aggregates is still influenced by its local availability.

2.3.2 Mineral Filler

Mineral filler occupies a good portion in the SMA mixes hence they do affect the quality of SMA mixes , therefore it becomes essential to study the effect of fillers in SMA .Various types mineral fillers are being used in SMA namely rock dust, slag dust, hydrated lime, hydraulic cement, fly ash, or other suitable mineral filler . they provide stiffness to the asphalt matrix , thus preventing the rutting and also helps in lowering the drain down . thus maintaining the durability .Fly ash is being widely used as mineral filler in SMA and is showing the requisite results as laid down by the Transportation departments guidelines. For example it has been extensively used in SMA pavements in **Georgia, Washington** and **Oregon**State [10, 11].

WestRandy C. and **S. Robert**evaluated the performance of Lime Kiln Dust (LKD) as mineral filler and compared its characteristics with that of stone dust as filler. It was conclude that the LKD used in this study performed as well or better than the rock dust mineral filler. They also emphasized on determination of a suitable maximum limit for available lime content of LKD for use as mineral filler for SMA which may attribute to premature pavement failure [13].

Research by **Walaa S. Mogawer**and **Kevin D. Stuart** on the Effects of Mineral Fillers on Properties of Stone Matrix Asphalt Mixture by using various mineral fillers shows that they significantly help in reducing the drain down in SMA and also adds to its rut resistance but the tests couldn't distinguish among SMA mixtures with good and bad mineral fillers [12]. Hence any mineral filler can be used based on its suitability and availability.

With this knowledge we have tried to implement cement as filler because of its wide availability and successful previous applications in SMA.

2.3.3 Bitumen

SMA contains very high content of bitumen as compared to conventional mixes i.e.> 6.5 %. It is used to bind the aggregates, fillers and stabilizing additives. Different studies on SMA have been conducted by using different bitumen grades namely bitumen of grade 60/70, polymer modified bitumen such as CRMB,PMB and others.

Huaxin Chenand**QinwuXu** used AH-90 to study the SMA properties [14]. Brown and Mallick (1994) used viscosity grade binder AC-20 for their research on SMA properties related to mixture design. It was found out that polymer modified bitumen provides better performance than unmodified bitumen.

Vikas Sharma and **ShwetaGoyal** studied the performance of SMA using CRMB and compared it with fiber reinforced sample. They found out that the indirect tensile strength, retained stability, resistance to moisture susceptibility, resistance to rutting, resistance to creep, and resistance to permeability and aging were found to improve with SMA mixtures with CRMB when compared with SMA mixtures with fibers as stabilizers .[15]

The study of the above paper gave a necessary idea of the influence of bitumen in SMA characteristics .In this project we have utilized 60/70 penetration grade of bitumen since we are trying to see the effect of fiber stabilized SMA with this basic unmodified bitumen .

2.3.4 Stabilizing Additives

Fibers are used as stabilizing additives in SMA. Since SMA is a gap graded mix and it contains large number of voids there is a significant chances of drain down of the binder matrix. Hence fibers are used as stabilizers which not only prevent the drain down but also add to the rut resistance. Various fibers used are cellulose fibers , mineral fibers , polymers and plastics etc.

2.3.4.1 Cellulose fiber

Cellulose fibers are fibers derived from plant or plant-based materials. They are of two types natural or manufactured .Natural cellulose fibers are fibers derived plants and even after processing are recognizable as parts of plants. For ex- cotton,flax,hemp,jute, ramie etc.

Manufactured or man- made cellulose fibers are fibers which have cellulose origin but whose chemical composition, structure, and properties are significantly modified during the manufacturing process but. Man-made fibers are spun and woven into a huge number of consumer and industrial products. Forexample rayon, acetate etc.

Cellulose is a polymeric sugar polysaccharide made up of repeating 1,4-8-an hydro glucose units connected to each other by 8-ether linkages. Strong intermolecular forces between chains, coupled with the high linearity of the cellulose molecule, account for the crystalline nature of cellulosic fibers.

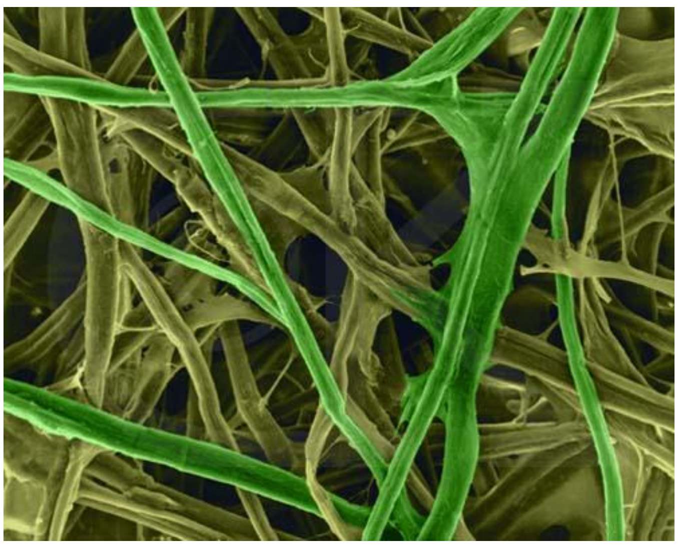

Figure 2.6 : Cellulose fiber as viewed through a microscope

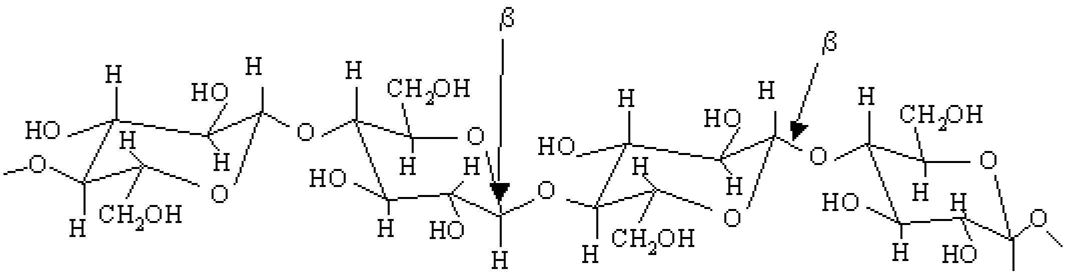

Figure 2.7: Cellulose fiber structural composition

2.3.4.2 Polymer

A polymer is a large molecule (macromolecule) composed of repeating structural units. These sub-units are typically connected by covalent chemical bonds. Natural polymer has cellulose as its main constituent. Fore.g. Natural rubber,shellas, amber etc. Synthetic polymers contains large class of compounds including natural and synthetic having varied properties. E.g.Synthetic , rubber, Bakelite, neoprene, nylon, PVC.

2.3.4.3 Bagasse fiber

Sugarcane refers to any of six to 37 species (depending on which taxonomic system is used) of tall perennial grasses of the genus Saccharum (family Poaceae, tribe Andropogoneae). They have stout, jointed, fibrous stalks that are rich in sugar, and measure two to six meters (six to 19 feet) tall .It is mainly cultivated in tropical and subtropical climates. The stalk of the sugarcane plant includes an outer rind which is a hard, wood-like fibrous substance. The rind surrounds a central core of pith, which bears nearly all of the sugar juice from which various sugar products are made. The outer surface of the rind has a thin, waxy epidermal layer. The sugarcane structure is shown in the figure.

Figure 2.8: Sugarcane crop

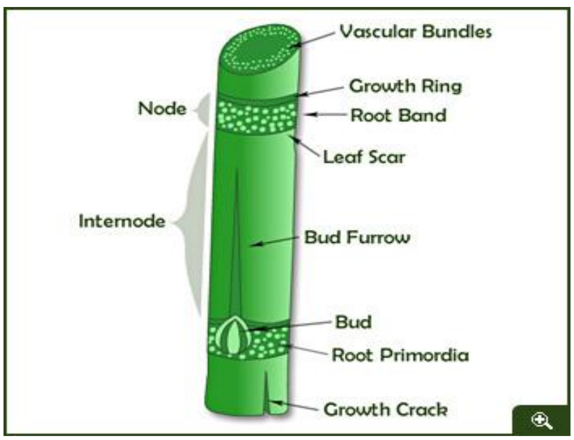

Figure 2.9: Schematic diagram of sugarcane Stalk

India is the second largest producer of sugarcane in the world. it produces about 40 million tonnes of bagasse every year .Bagasse is a derived from sugarcane which is essentially a fibrous residue that remains after crushing the stalks, and contains short fibers .Due to crushing it breaks down into small pieces and the milling process takes out all the juices.). It consists of water, fibers, and small amounts of soluble solids which may vary depending on various conditions.

Figure 2.10 Bagasse fiber

A typical chemical analysis of bagasse might be (on a washed and dried basis):

Table 1.1 Chemical composition of bagasse

Component	Percent
Cellulose	45-55%
Hemicellulose	20-25%
Lignin	18-24%
Ash	1-4%
Waxes	<1%

Presently 85% of bagasse production is burnt. Even so, there is an excess of bagasse. Some of the major fields in which it is used are:

- Fuel(ethanol) and power production
- Paper production
- Agro feed stock

Several people have used several fibers in SMA be it natural orman-made and have obtained good results .

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Huaxin Chen and **QinwuXu** used five different polymers (two polyesters, one polyacrylonitrile, one ligninand one asbestos) in SMA to study the fibers' physical properties, reinforcing effects and mechanisms for stabilizing and reinforcing asphalt binder. Test were conducted to compare water absorption,drain down andtemperature effects on these fibers. Results indicate that fibers effectively improve asphalt binder's resistance to rutting and flow, and dynamic shear modulus. Asphalt matrix gets reinforced through the functions of spatial networking, adhesion and stabilization of asphalt binder. Polyester and polyacrylonitrile fibers seem to have greater network effect than the lignin and asbestos fibers, and their antenna features at fibers' ends further strengthens this effect. The lignin fiber has the highest water absorption while lowest thermostability. The lignin and asbestos fibers posegreater effects of asphalt absorption and stabilization than do polymer fibers [16].

EsmaeilAhmadinia,**MajidZargar**, **Mohamed RehanKarim** and **MahrezAbdelaziz, PayamShafigh** studied the effect of waste plastic bottles (Polyethylene Terephthalate (PET)) in SMA by varying its quantity and observing its engineering properties. The results were very positive which not only improve SMA quality but also proved to be environment friendly by using waste plastic bottles .[17]

Sandra Oda,**José LeomarFernandes Jr**. and**JesnerSereniIldefonso**analysed use of natural fibers and asphalt rubber binder in discontinuous asphalt mixtures. In this research work they utilized four different fiber coconut, sisal, cellulose and polyester in the asphalt binder. Coconut and sisal are plentily available in Brazil where the study was conducted. The results of mechanical tests (tensile strengthand modulus of resilience) demonstrate that blends with natural fibers showed high resistance, while preventing the asphalt to drain down. [18]

The purpose of using bagasse fiber is because of its high availability and non usability in India. Hence we are trying to implement it in our research work so as to prove its worthiness in transportation industry

2.4 TESTS TO BE CONDUCTED

Most of research work done in SMA includes the Marshall Stability tests for determining the flow and stability for SMA. For drain down study two tests are basically used, one is wire basket method and theother isSchellenberg binder drainage test. We will be comparing the drain down by both the methods. Static indirect tensile tests will also be performed to determine the mix strength at various temperatures. These are the tests we will be following in our work to determine the SMA properties.

2.5 CONCLUDING REMARKS

A detailed review of the literatures gave a very good insight of what previous works have been done by researchers across the globe. This study not only gave us a good idea of the SMA and its material properties but it has also influenced the approach in which the work is to carry. Hence, the literature review study has given us a proper direction and idea to carry out the project.

CHAPTER 3
EXPERIMENTAL OVERVIEW

EXPERIMENTAL OVERVIEW

3.1 MATERIALS USED

1. Coarse and Fine aggregate
2. Bitumen as binder (60/70)
3. Fiber as stabilizer (Bagasse fiber)
4. Cement as filler

3.1.1 Test on aggregates

Aggregates were taken as perMORT&H specifications for the preparation of SMAmixes. Aggregates used were collected from a local source and crushed using a Jaw crusher. Following are the aggregates used:

3.1.1.1 Coarse Aggregates

These are the aggregates passing through the 16 mm sieve and retained on the 4.75 mm sieve for the mix. The test on the aggregates performed was as follows:

- **Aggregate Crushing Value (IS:2386 (PIV))**

Aggregate crushing value = (B/A) x 100
where
B = weight of fraction passing the appropriate sieve, and
A = weight of surface-dry sample.

Table 3.1Aggregate Crushing Value

Wt. Of oven dried sample (in gm) A	Wt. of aggregate retained through 2.36mm IS sieve (in gm)	Wt. of aggregate Passing through 2.36mm IS sieve (in gm) B	Crushing Value	Avg Impact value (%)
3.162	2.600	0.562	17.77	17.39
3.161	2.593	0.568	17.01	

- **Impact Value Test (IS:2386 (PIV))**

Impact Value= (B/A)*100

Where A = Wt. Of ovendried sample(in gm)

B= Wt. of passingaggregate (ingm)

Table 3.2 Impact values

Sl No.	Wt. Of oven dried sample (in gm)A	Wt. of aggregate retained through 2.36mm IS sieve (in gm)	Wt. of passing aggregate (in gm)B	Impact Value(%)	Avg. Imapct Value(%)
1	673.5	602.4	71.1	10.56	
2	693.1	619.4	73.7	10.63	10.75
3	678	605.4	72.6	11.06	

- **Abrasion Value Test(IS:2386 (PIV)**
  For Class B
  20-12.5 mm= 2500gm
  12.5-10mm=2500gm
  No of balls=11
  Abrasion value =(B/A)*100 ,
  Where B= Wt. of passingaggregate (in gm)

  A= Wt. Of oven dried sample (in gm)

Table 3.3 Abrasion value test

Wt. Of oven dried sample (in gm) A	Wt. of aggregate retained through 2.36mm IS sieve (in gm)	Wt. of passing aggregate (in gm) B	Abrasion Value
5000	3969	1031	20.52

- **Flakiness and Elongation Index(IS:2386 (PI))**

  The Flakiness and elongation index was determined to be 8.4 and 19.9 % respectively.

- **Water Absorption Test(IS:2386 (PIII))**
  Water absorption is given by equation:$\frac{W1-W2}{W2} * 100$

  Where W1= Weight of saturated dry sample.

  W2= Weight of material + basket suspended in water

Table 3.4 Water absorption Test

Weight of saturated sample W1(gm)	Weight of material + basket suspended in water W2(gm)	Water absorption(%)
1996	2014	0.90

- **Specific Gravity Test:(IS:2386 (PIII))**
  Specific gravity of coarse aggregate is determined by $\frac{W1}{W1-(W3-W2)} * 100$

Where W1= Weight of saturated dry sample.

W2=Weight of dry basket

W3=Weight of basket+ material in water

Table 3.5 Specific Gravity Test

Weight of dry basket W2(gm)	Weight of basket+material in water W3 (gm)	Weight of saturated dry sampleW1(gm)	Specific gravity
886	1275	2000	2.76

3.1.1.2 Fine Aggregates:(IS:2386 (PIII))

These are fines having fractions passing through 4.75 mm sieve and retaining on 0.075 mm IS sieve. The specific gravity was found out to be 2.72.

3.1.2 Filler:

Filler is used as a binding agent to bind aggregate, bitumen and fiber. It should pass through a 0.075 mm IS sieve .Varieties of fillers such as stone dust , fly ash , glass powder , cement etc can be used in SMA Portland slag cement collected locally was used in the SMA mixes.

- **Specific Gravity of filler:**The specific gravity of the filler material was determined by Le ChatlierApparatus. Specific gravity was given by:

Table 3.6 Specific Gravity of filler

Sample No	Air temp (oC)	Weight of the cement (gm)	Initial reading of the flask (ml)	Final reading of the flask (ml)	Volume of cement particles (cc)	Specific gravity (gm/cc)	Avg Specific gravity (gm/cc)
1	25	60	0.5	19.5	19	3.15	3.13
2	25	60	0.7	20	19.3	3.11	

3.1.3 BINDERS:

It is the main agent used for the binding of aggregates and fibers, and it also serves the purpose of filling up of the voids. Conventional bitumen of penetration grade 60/70 was used in the mix.

- **Penetration Value (IS1203-1978)**

Table 3.7 Penetration Value

Sample No	Penetration dial reading	Penetratin Value
Sample 1	68	67.66
	65	
	70	
Sample 2	65	67.33
	70	
	67	

Table 3.8 Physical properties of SMA components

TEST ON SMA COMPNENTS	TEST METHODS	TEST RESULTS	
Aggregate crushing value	IS:2386 (PIV)	17.39	18
Impact value	IS:2386 (PIV)	10.5	18
Abrasion value	IS:2386 (PIV)	20.52	25
Flakiness Index	IS:2386 (PI)	8.4%	30
Elongation Index	IS:2386 (PI)	19.9%	30
Water Absorption	IS:2386 (PIII)	0.90%	2%
Specific gravity of coarse aggregate	IS:2386 (PIII)	2.76	2.6-2.8
Specific gravity of fine aggregates	IS:2386 (PIII)	2.72	2.6-2.8
Penetration value of binder	IS1203-1978	67.495	60-40
Softening point	IS1205-1978	48.5	35-50

3.1.4 FIBERS:

Fibers is being used in SMA as a stabilizing agent and to reduce the drain down significantly .Various fibers have been used in various studies showing very good results. Here we have tried to use bagasse fiber as a stabilizer in the mix.

The fibers were collected locally from sugar mills. . The bagasse collected was having a varied length with approximately most of them lying between 5 cm to 12 cm.They were first washed properly to remove the unwanted materials and then dried. After drying, the rind portions were carefully removed from the bagasse and were subsequently cut into an approximate length of 5 mm. The fibers were having a thickness of approximately 1mm to 3mm which is determined from a rough estimation. 0.3% fiber was used as given in MORTH specification.

3.2 PREPARATION OF MIXES

Procedure followed for the preparation of mixes was as follows:

3.2.1 Sieve Analysis:

Sieve analysis was done according to the MORTH specification to obtain the required gradation as shown in Table. 1200 gm of materials were used to obtain this gradation and for the preparation of the mix.

Table 3.8 Gradation table for sample with fibers

Sieve size (mm)	%age retained	4%	4.50%	5.00%	5.50%	6.00%	7.00%
		0%	0%	0%	0%	0%	0%
		1148.4	1142.4	1136.4	1130.4	1124.4	1112.4
13.2	5%	57.42	57.12	56.82	56.62	56.22	55.62
9.5	33%	378.972	376.992	375.012	373.032	371.052	376.092
4.75	29.5%	338.778	337.008	335.238	333.468	331.698	328.158
2.36	8%	91.872	91.392	90.912	90.432	89.952	88.992
1.8	3.50%	40.194	39.984	39.774	39.564	39.354	38.934
0.6	2.50%	28.71	28.56	28.41	28.26	28.11	27.81
0.3	2.50%	28.71	28.56	28.41	28.26	28.11	27.81
0.15	4%	45.396	45.696	45.456	45,216	44.976	44.496
0.075	1.50%	17.226	17.136	17.046	16.956	16.866	16.686
Filler	10.50%	120.582	119.952	119.322	118.692	118.062	116.802
Binder		48	54	60	66	72	84
Fiber (gm)		3.6	3.6	3.6	3.6	3.6	3.6

Table 3.9 Gradation table for sample without fibers

Sieve size (mm)	%age retained	4%	4.50%	5.00%	5.50%	6.60%	7.00%
		1152	1146	1140	1134	1128	1116
13.2	5%	57.6	57.3	57	56.7	56.4	55.8
9.5	33%	380.16	378.18	376.2	374.22	372.24	368.28
4.75	29.5%	339.84	338.07	336.3	332.53	332.76	329.22
2.36	8%	92.16	91.68	91.2	90.72	90.24	89.28
1.18	3.50%	40.32	40.11	39.9	39.69	39.48	39.06
0.6	2.50%	28.8	28.65	28.5	28.35	28.2	27.9
0.3	2.50%	28.8	28.65	28.5	28.35	28.2	27.9
0.15	4%	46.08	45.84	45.6	45.36	45.12	44.64
0.075	1.50%	17.28	17.19	17.1	17.01	16.92	16.74
Filler	10.50%	120.96	120.33	119.7	119.07	118.44	117.18
Binder		48	54	60	66	72	84

3.2.1.1 Sample Preparation:

Following steps were performed for the preparation of the mixes**:**

- **Weighing of sample.**

3 samples each with binder content 4, 4.5% 5%, 5.5%, 6%, 6.5%, 7% were weighed according to the given gradation in Table. The samples were weighed according to the tables for with and without fiber.

- **Heating of aggregates :**

The weighed samples were heated in an oven at a temperature of about 1700 C for hrs so as to remove any moisture from it as well as to bring the sample to the temperature supporting its easy mixing. Overheating of sample was avoided.

- **Heating of bitumen :**

The 60/70 bitumen was heated at high temperature to ensure it is liquefied properly for the easy mixing in the SMA mix.

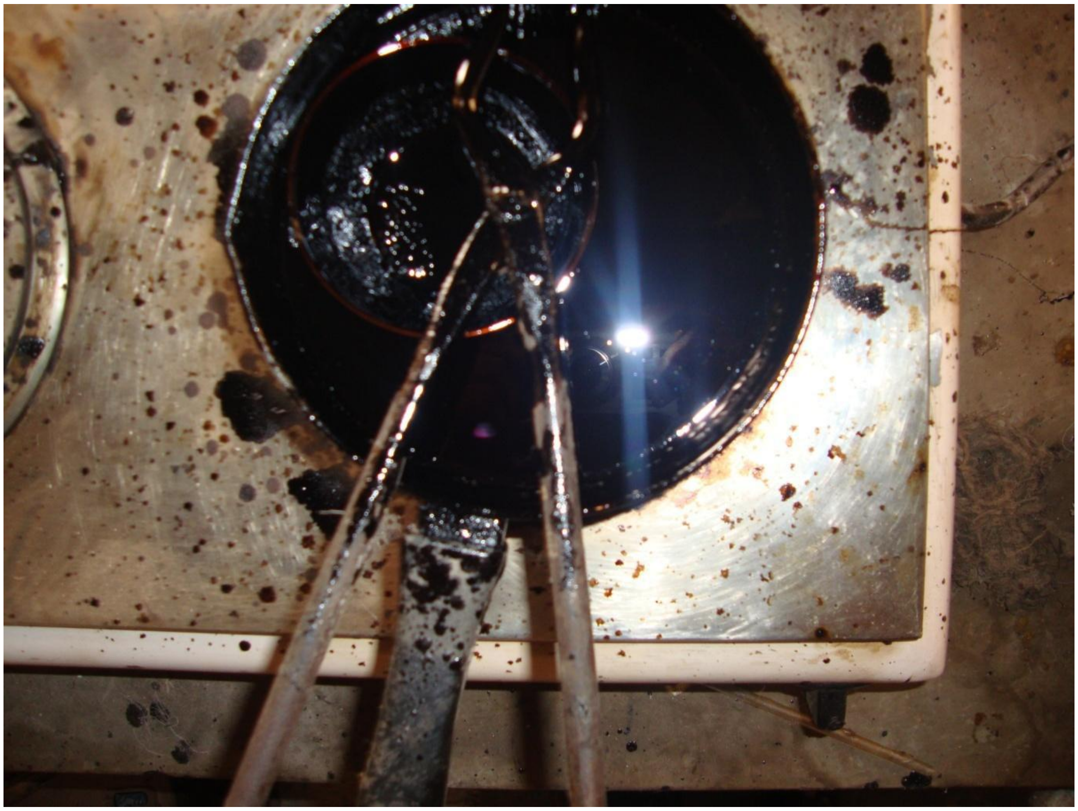

Figure 3.1 Heating of Bitumen

- **Mixing of components:**

The components were mixed in a suitable container and were mixed properly to ensure forming of a homogeneous bituminous mix. The mixture was stirred until the entire contents exhibit a shining bituminous surface coating.

Figure 3.2 Mixing of components

- **Putting in mould**

The prepared mixture was transferred to a pre heated mould as quickly as possible so as to ensure that the mixture does not cool before hammering. The diameter of the mould is 100 mm. The mixture was laid down in 3 layers with proper tamping done after putting each layer.

Figure 3.3 A typical mould

- **Hammering (Compaction)**

The mixture was then compacted with the help of a hammer having a dimension of and falling from a height of mm. 50 blows were given on each face of the sample. Research has shown that more blows would cause the deterioration of aggregates. For hammering the mould was attached to a fixed arrangement to prevent that staggering of mould during hammering. A piece of paper of size of mould was put in mould over fitting so that mix is not glued to fitting. For he same purpose oiling was done in inner faces of mould and bottom of hammer.

Figure 3.4 A typical Hammer

- **Finalizing the sample**

The sample was then taken out of the mould by a suitable instrument after 24 hrs. Name stickers representing the binder content and sample number were glued to the sample which will be useful while performing the tests.

3.3 TESTS

3.3.1Preparation of sample for the tests

The samples taken out of the mould after preparation undergoes a number of procedures for the tests. First the dimensionsi.e. the heights and the diameter are determined. Height of the samples was taken at four different points. Then the sample was weighed before being dipped into the paraffin. Then it was dipped in paraffin, it was to ensure that water does not enter into the pores in the samples. Therefore the sample is coated with a thin film of paraffin. The paraffin coated samples were then weighed in air as well in water carefully. This is done to find out the volume of water displaced which is used for the calculation of bulk specific gravity of the mix. The code specifies that for Marshall Test the sample has to be placed in water bath for 30 (+_ 5 mins) at a temperature of about 60^{o}C (-+ 1OC). The time of testing between takings out of sample from water bath and testing should not exceed 30 secs.

3.3.2 Marshall Test

The Marshall test is used widely throughout the world to determine the stability and flow characteristics of bituminous mixes. In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically till its failure First the Marshall specimens are prepared as per the given specifications . The physical properties (dimension, weight etc) were recorded. Before testing the code specifies that for Marshall Test the sample has to be placed in water bath for 30 (+_ 5 mins) at a temperature of about 60^{o}C (-+ 1OC) . The time of testing between taking out of sample from water bath and testing should not exceed 30 secs .Load is applied vertically at a rate of 50 mm per minute on the sample at 60o C and its stability and flow value were recorded from the respective gauges .There are two major features of the Marshall method of mix design.

(i) Density-voids analysis and
(ii) Stability-flow tests

The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value is the deformation that the test specimen undergoes during loadingupto the maximum load.

- **Equipment Description [20]**

- **Breaking Head** - the breaking head shall consist of upper and lower cylindrical segmentsor test heads having an inside radius of curvature of 50.8 mm accurately machined. Thelower segment shall be mounted on a base having two perpendicular guide rods or postsextending upward. Guide sleeves in the upper segment shall be in such a position as todirect the two segments together without appreciable binding or lose motion on the guiderods.

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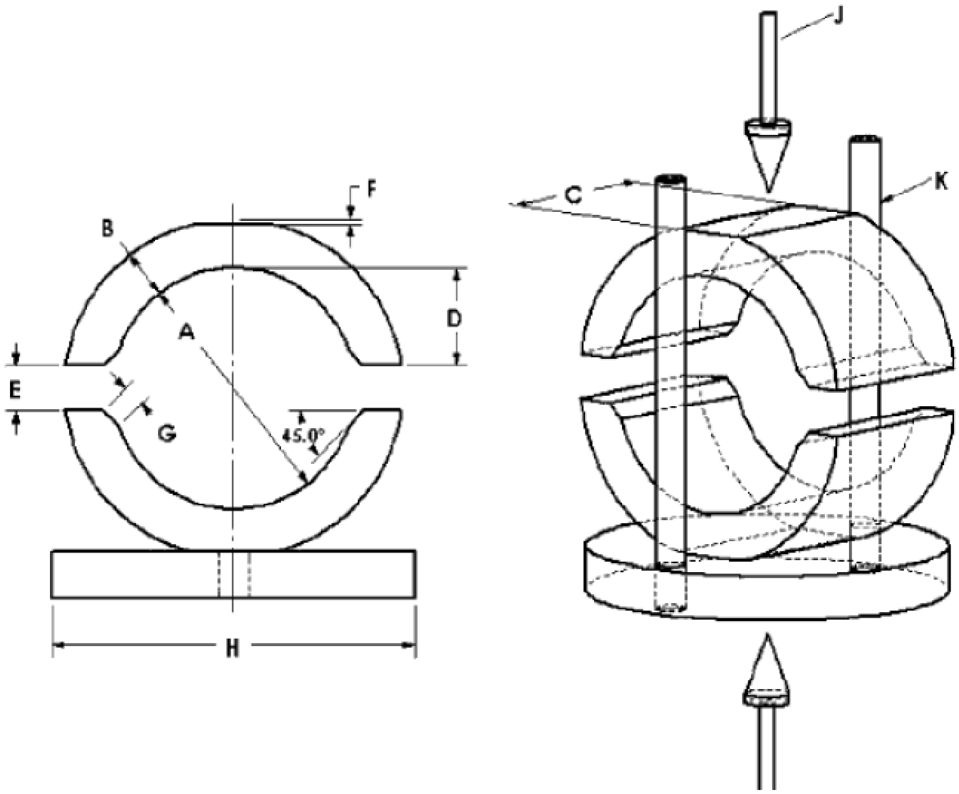

- **Loading Jack** - the loading jack shall consist of a screw jack mounted in a testing frame and shall produce a uniform vertical movement of 50.8 mm/minute. An electric motor may be attached to the jacking mechanism.

- **Ring Dynamometer Assembly or Electronic Equivalent** - one ring dynamometer of 2267kg capacity and sensitivity of 4.536 kg up to 453.6 kg and 11.34 kg between 453.6 and2267 kg shall be equipped with a micrometer dial. The micrometer dial shall be graduated in 0.0025 mm. Upper and lower ring dynamometer attachments are required forfastening the ring dynamometer to the testing frame and transmitting the load to thebreaking head.

- **Flow meter** - The flow meter shall consist of a guide sleeve and a gauge. The activating pin of the gauge shall slide inside the guide sleeve with a slight amount of frictionalresistance. The guide sleeve shall slide freely over the guide rod of the breaking head.The flow meter gauge shall be adjusted to zero when placed in position on the breakinghead when each individual test specimen is inserted between the breaking head segments.

- **Water Bath -** the water bath shall be at least 152 mm deep and shall be thermostatically Controlled so as to maintain the bath at 60 ± 1^{O} C. The tank shall have a perforated false bottom or be equipped with a shelf for supporting specimens 51 mm above the bottom of the bath.

- **Air Bath -** the air bath for asphalt cutback mixtures shall be thermostatically controlled and shall maintain the air temperature at 25 ± 1^{O} C.

Figure 3.5 Marshall Apparatus

3.3.3 Draindown Test

Several methods are used worldwide for determining the draindown of the bituminous mixes. Here we have used two methods to determine the draindown in the SMA sample given in IRC SP79, 2008 (outline of ASTM D6930) [21].

- **Wire Basket Method :**

The draindown characteristics were determine at the anticipated plant producing temperatures. Four samples were prepared for each mixes. The mix was prepared using 0.2 %, 0.3% and 0.4% fibers for which the required gradations of aggregates wereevaluated. Tests were performed at theoptimum bitumen content (OBC). The mix was first, kept in a loose state and was transferred as such into a wire basket assembly without consolidating it. This preparation was kept in oven for three hours at 150^{O} C .The bitumen drainage occurring after this time was determined to obtain the required drain down. A catch plate is used to hold the drainedmaterial. Average of two draindown was determined for each mix with and without fiber. Draindown was evaluated using the following formula:

$$\{(D-C)/ (B-A)\}*100$$

Where,

A= mass of the empty wire basket, g
B=mass of wire basket plus sample, g
C=mass of the empty catch plate, g
D=mass of the catch plate plus drained material, g

3.3.4 Static Indirect Tensile Test:

This test is used to determine the tensile strength of compacted bituminous mixtures .The IDT strength of bituminous mixtures is conducted be loading a cylindrical specimen across its vertical diametral plane at a specific rate of deformation and test temperature. The peak load at failure is recorded and used to calculate the IDT strength of the specimen.

The values of IDT strength may be used to evaluate the relative quality of bituminous mixes in conjunction with laboratory mix design testing and for estimating the potential for rutting or cracking. The results can also be used to determine the potential for field pavement moisture – conditioned or unconditioned specimens.

Deformation rate used for the test was 51 mm/min. Two loading strips, 13 mm (1/2□) wide, 13 mm deep and 75 mm long, made up of stainless steel were used to transfer the applied load to the specimen .Marshall samples were prepared with OBC using fiber . The samples were kept in the water bath for 30 mins at varying temperatures of 5, 10, 15, 20,25,30,35, and 40^{o}C. The Perspex water bath maintained at the same test temperature was placed on the bottom plate of the Marshall apparatus and the sample was put inside it. Care was taken such that load is applied along the vertical diametrical plane. The load was applied till failure and the failure load was noted using the dial gauges .The IDT was calculated using the formula:

$$St = \frac{2P}{\pi * t * D} \quad \text{Kpa}$$

Where,
S_t = Indirect Tensile Strength, kPa
P = Maximum Load, N
t = Specimen height before testing, mm
D = Specimen Diameter, mm

Figure 3.6 Indirect tensile test in Progress

CHAPTER 4
ANALYSIS AND DISCUSSION

ANALYSIS AND DISCUSSION

The previous chapter deals with the experiments that are performed in details. In this chapter the results of the experiments performed are presented, analyzed and discussed.

4.1 Parameters Used

1. **Bulk specific gravity (G_{sb})** of aggregates

   $$Gsb = \frac{\text{Magg}}{\text{volume of (aggregate mass +air void in aggregate+absorbed bitumen}}$$

2. **Theoretical maximum specific gravity (G_{mm})** of the mix

   $$Gmm = \frac{\text{Mmix}}{\text{volume of (mix−air vods)}}$$

3. **Bulk specific gravity (G_{mb})** of the mix

   $$Gmb = \frac{\text{Mmix}}{\text{bulk volume of the mix}}$$

4. **Voids in mineral aggregates (VMA)**

   $$VMA = \left[\left(\frac{Mmix}{Gmb} - \frac{Mmix\,Ps}{Gsb}\right) / \frac{Mmix}{Gmb}\right] * 100$$

   Where P_s is the percent of aggregate present, by total mass of the mix (that is, $M_{agg} = P_s * M_{mix}$)

   So $VMA = (1 - Gmb/Gsb) * Ps * 100$

5. **Air voids (VA)**

   $$VA = \left[1 - \frac{Gmb}{Gmm}\right] * 100$$

6. **Voids filled with bitumen (VFB)**

   $$VFB = \frac{VMA - VA}{VMA} * 100$$

4.2 Marshall Test Results

The Marshall properties of the experiments performed are presented and discussed below:

4.2.1 Dimensions of the sample

The dimensions of the samples completely prepared with and without fibers are given below:

Table 4.1 Dimension of the samples without fibers

Binder %	D	H1	H2	H3	H4	avg H
4	10	6	6	6.1	6.1	6.05
		6.2	6.2	6.3	6.3	6.25
		6	6.1	6.2	6.3	6.15
4.5	10	6	6.1	6	6	6.025
		6.2	6.1	6.1	6.1	6.125
		6	6.2	6.1	6.1	6.1
5	10	6.3	6.1	6.2	6.2	6.2
		6	6.2	6.1	6.1	6.1
		6.1	6.1	6.1	6.1	6.1
5.5	10	6	6.3	6.1	6.1	6.125
		6.1	6.1	6.1	6.1	6.1
		6	5.8	5.9	5.9	5.9
6	10	6.1	6.3	6.2	6.2	6.2
		6.3	5.9	6.1	6.1	6.1
		6.1	6.1	6.1	6.1	6.1
7	10	6.1	6	6	6	6.025
		6	6.1	6	6	6.025
		6.1	6.1	6.1	6.1	6.1

Table 4.2 Dimension of the samples with fibers

Binder %	D	H1	H2	H3	H4	avg H
4	10	6.4	6.3	6.3	6.2	6.3
4	10	6	6.1	6.1	6.4	6.15
4	10	6	6.2	6.2	6.3	6.175
4.5	10	6.1	6.3	6.1	6.2	6.175
4.5	10	6.1	6.1	6	6.1	6.075
4.5	10	6	6.2	6.3	5.9	6.1
5	10	5.9	5.9	5.8	6	5.9
5	10	6	5.8	5.8	6.1	5.925
5	10	6	6	6.1	6.1	6.05
5.5	10	6.3	5.8	5.8	6.2	6.025
5.5	10	5.9	5.9	6	6.1	5.975
5.5	10	5.9	5.8	5.9	6.1	5.925
6	10	6	6	6.1	6	6.025
6	10	6	6	6.1	5.9	6
6	10	6	6.1	6.1	5.8	6
7	10	6.2	6	6	6.1	6.075
7	10	6.1	5.9	5.9	6.2	6.025

4.2.2 Stability and flow values

The stability and flow values of the samples with and without fibers were determined by Marshall Apparatus. The values are given below:

Table 4.3 Stability and flow without fibers

Binder %	WSA	Wpcsa	Wpcsw	Stability n	Flow	Stability (kn)	avg Flow
4	1205	1217	720	242	2.1	7.18858004	2.13
	1204	1218	727	213	1.9	6.327138631	
	1202	1216	731	262	2.4	7.782677564	
4.5	1198	1211	718	268	2.5	7.960906822	2.36
	1197	1210	717	282	2	8.376775088	
	1200	1211	722	266	2.6	7.901497069	
5	1205	1216	721	254	3.4	7.545038555	2.83
	1199	1209	718	275	2.9	8.168840955	
	1205	1217	722	260	2.2	7.723267812	
5.5	1205	1203	724	297	5	8.822348231	3.7
	1199	1205	720	245	3	7.277694669	
	1205	1203	714	239	3.1	7.099465412	
6	1195	1205	716	229	4.5	6.80241665	4.03
	1196	1205	716	235	3.9	6.980645907	
	1197	1208	718	234	3.7	6.950941031	
7	1188	1197	705	227	4.8	6.743006897	5.3
	1195	1204	709	232	5.8	6.891531278	
	1187	1196	704	202	5.3	6.000384992	

Table 4.4 Stability and flow with fibers

binder	WSA	Wpcsa	Wpcsw	stability	FLOW	avg Flow	avg Stability
4	1197	1214	717	226	2.6	2.533	7.16
4	1198	1212	715	237	2.9		
4	1195	1216	709	248	2.1		
4.5	1195	1208	719	261	2.8	3.03	7.52
4.5	1192	1207	712	264	3.1		
4.5	1194	1208	715	238	3.2		
5	1195	1202	722	294	3	3.333	8.7
5	1198	1205	723	286	3.8		
5	1195	1202	721	299	3.2		
5.5	1207	1212	726	290	4.3	3.67	8.05
5.5	1196	1201	720	255	2.9		
5.5	1202	1207	724	268	3.8		
6	1189	1196	710	246	4.9	4.6	6.87
6	1194	1201	714	214	4.3		
6	1185	1193	709	234	4.6		
7	1181	1189	701	202	5.4	6.95	5.99
7	1189	1196	708	201	8.5		

4.3.3 Calculations and results

The Marshall properties determined from the parameters above are given below:

Table 4.5 Marshall Parameters of samples Without fibers

Binder %	BULK V	Gmb	Gsb	avg VMA	VMA	Gmm	VA	avg VA	VFB
4	483.666	2.51	2.786	13.39	13.51	2.62	4.19	4.066667	69.89884
	475.444	2.53			12.82		3.43		
	469.4444	2.54			13.85		4.58		
4.5	478.5556	2.53	2.785	13.24	13.24	2.6	2.69	2.816667	78.72608
	478.5556	2.52			13.58		3.07		
	476.7778	2.53			12.9		2.69		
5	482.7778	2.52	2.785	14.01	14.03	2.587	2.59	2.46	82.46614
	479.8889	2.52			14.03		2.59		
	481.6667	2.53			13.96		2.2		
5.5	481.2222	2.57	2.786	14.29	12.82	2.57	1.56	1.79	86.03744
	478.3333	2.53			14.18		3.5		
	491.2222	2.48			15.87		0.31		
6	477.889	2.52	2.786	15.2	14.97	2.55	1.17	1.43	90.44756
	479	2.51			15.32		1.56		
	477.7778	2.51			15.31		1.56		
7	482	2.49	2.786	16.74	16.88	2.52	1.19	1.02333	93.93762
	485	2.4962			16.67		0.94		
	479.62	2.4963			16.67		0.94		

Table 4.6 Marshall Parameters of samples With fibers

binder	Bulk V	Gmb	Gsb	VMA	avg VMA	Gmm	v A	avg VA	VFA
4	478.11	2.54	2.797	12.82	13.39	2.54	2.93	4.218	67.09
4	481.44	2.52		13.5		2.52	3.695		
4	483.66	2.51		13.85		2.51	4.07		
4.5	474.55	2.55	2.795	12.87	13.32	2.55	1.756	3.565	72.94
4.5	478.33	2.52		13.89		2.52	2.912		
4.5	477.44	2.54		13.21		2.54	2.142		
5	472.22	2.55	2.794	13.29	13.16	2.55	1.055	1.3136	90.01
5	474.22	2.55		13.24		2.54	1.443		
5	473.23	2.56		12.96		2.55	1.443		
5.5	478.44	2.53	2.793	14.39	14.5	2.53	1.102	1.2323	91.5
5.5	475.44	2.51		15.075		2.51	1.884		
5.5	477.44	2.54		14.06		2.54	0.711		
6	478.22	2.5	2.794	15.89	15.66	2.5	1.617	1.352	91.36
6	479.22	2.51		15.55		2.51	1.22		
6	475.11	2.51		15.55		2.51	1.22		
7	479.11	2.48	2.794	17.44	16.39	2.48	0.998	0.798	95.13
7	480.22	2.49		15.34		2.48	0.598		

4.3 DISCUSSION OF RESULTS

4.3.1 Stability vs. bitumen content

Table 4.7 Table for Stability vs. binder %

Binder%	Stability without fiber	Stability with fiber
4	6.65	7.16
4.5	8.079	7.52
5	7.812	8.7
5.5	7.732	8.05
6	6.91	6.87
7	6.54	5.99

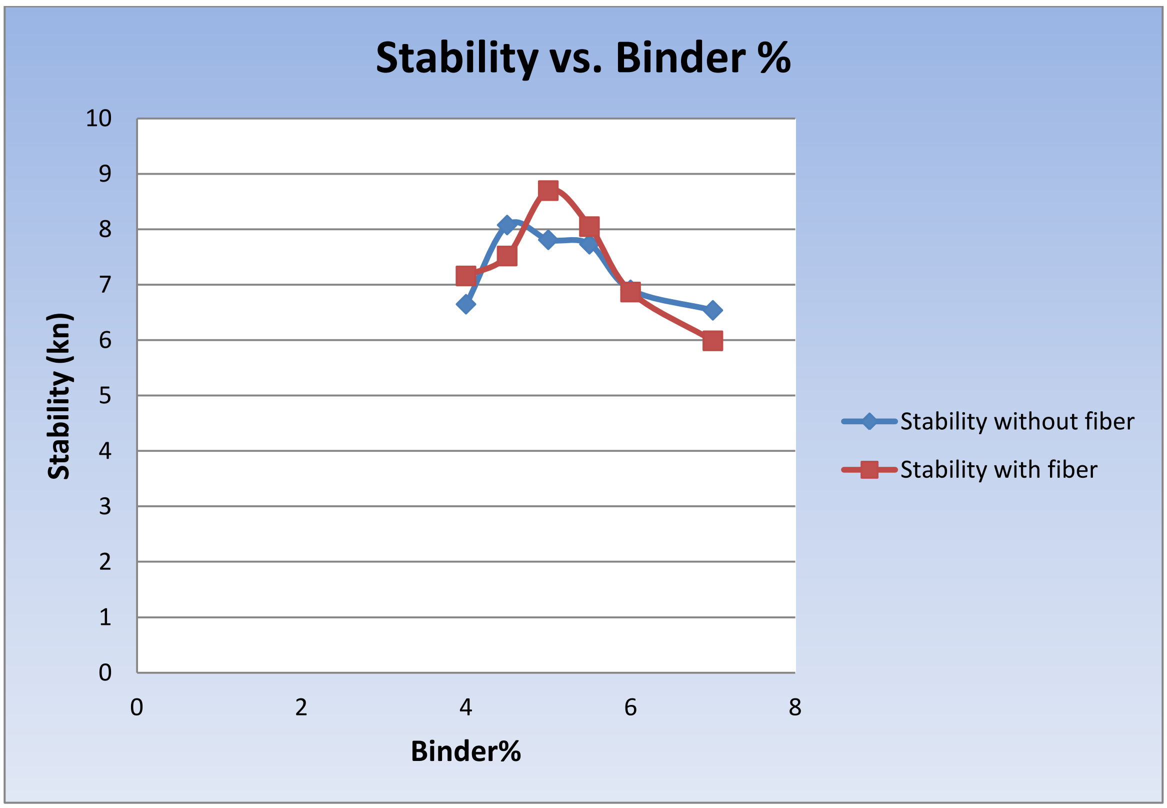

Figure 4.1 Stability vs. bitumen content

4.3.2 Flow vs. Bitumen content

Table 4.8 Flow vs. Binder %

binder %	Flow values without fiber	Flow values with fiber
4	2.13	2.533
4.5	2.36	3.03
5	2.83	3.333
5.5	3.7	3.67
6	4.03	4.6
7	5.3	6.95

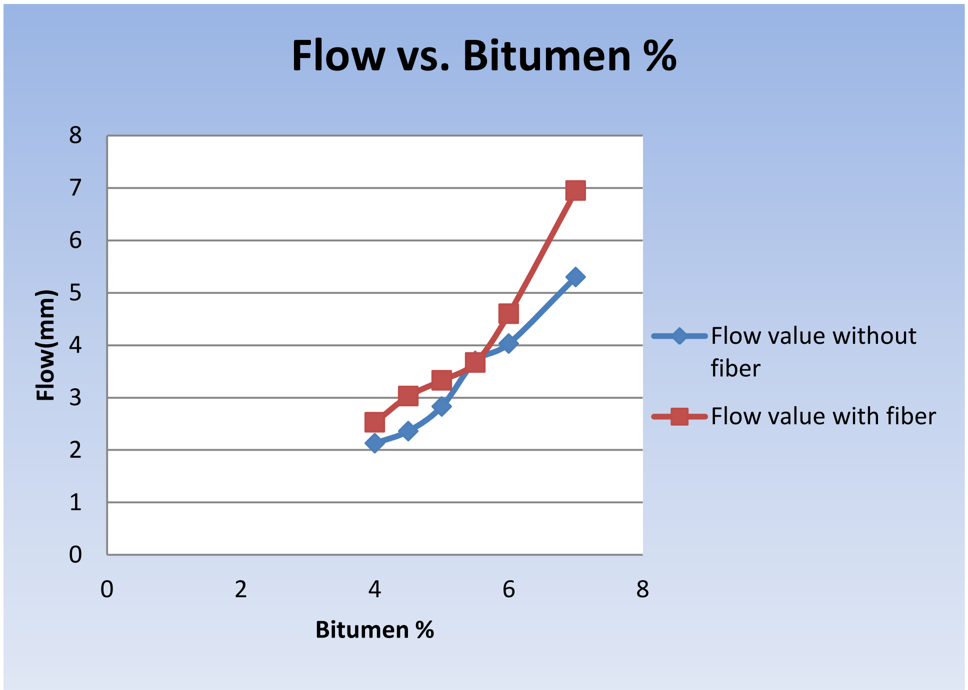

Figure 4.2 Flow vs. Binder %

4.3.3 VMA vs. binder content

Table 4.8 VMA vs. Binder content

Binder%	VMA without fiber	VMA with fiber
4	13.39	13.39
4.5	13.24	13.32
5	14.01	13.16
5.5	14.29	15.5
6	15.2	15.66
7	16.74	16.39

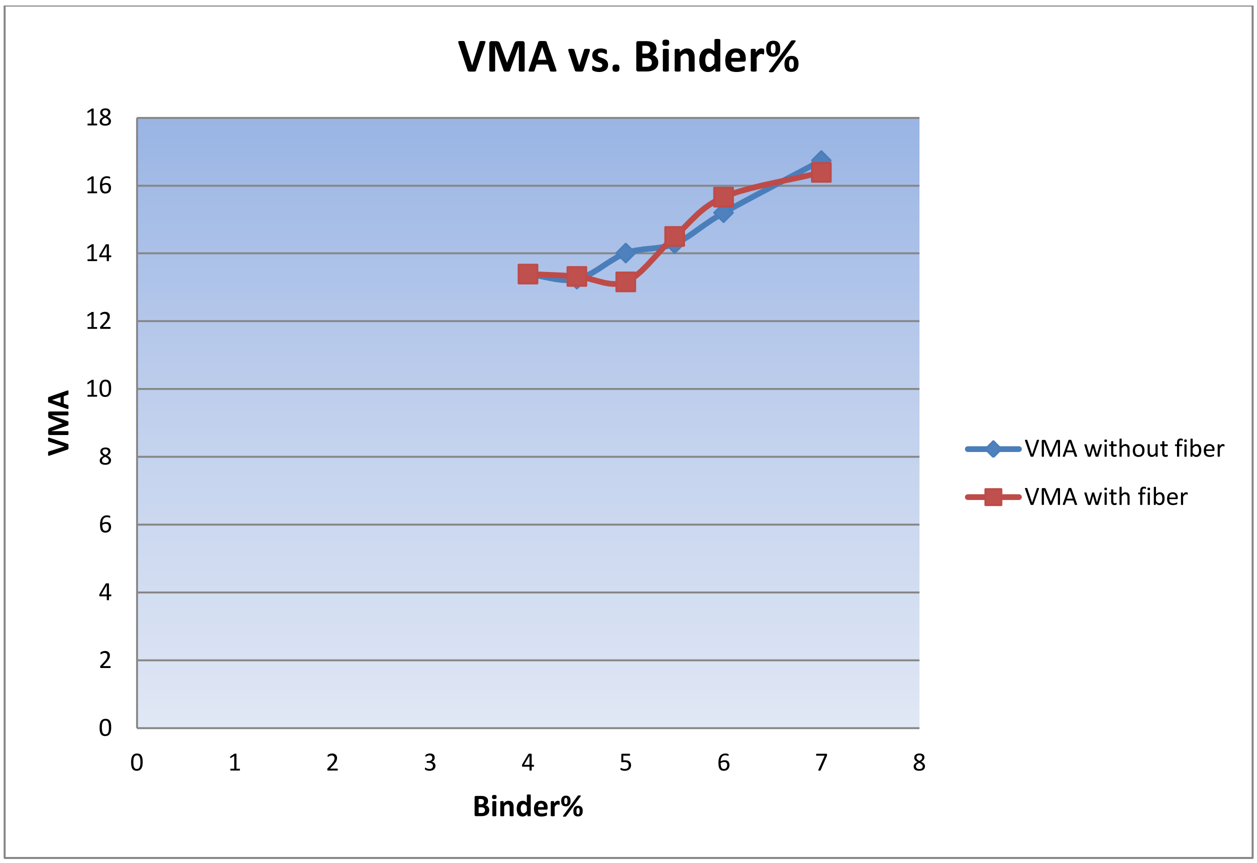

Figure 4.3 VMA vs. Binder content

4.3.4 VA vs. Bitumen content

Table 4.9 VA vs. Bitumen content

Binder%	VA without fiber	VA with fiber
4	4.067	4.218
4.5	2.816	3.565
5	2.46	1.3136
5.5	1.74	1.2323
6	1.43	1.352
7	1.23	0.798

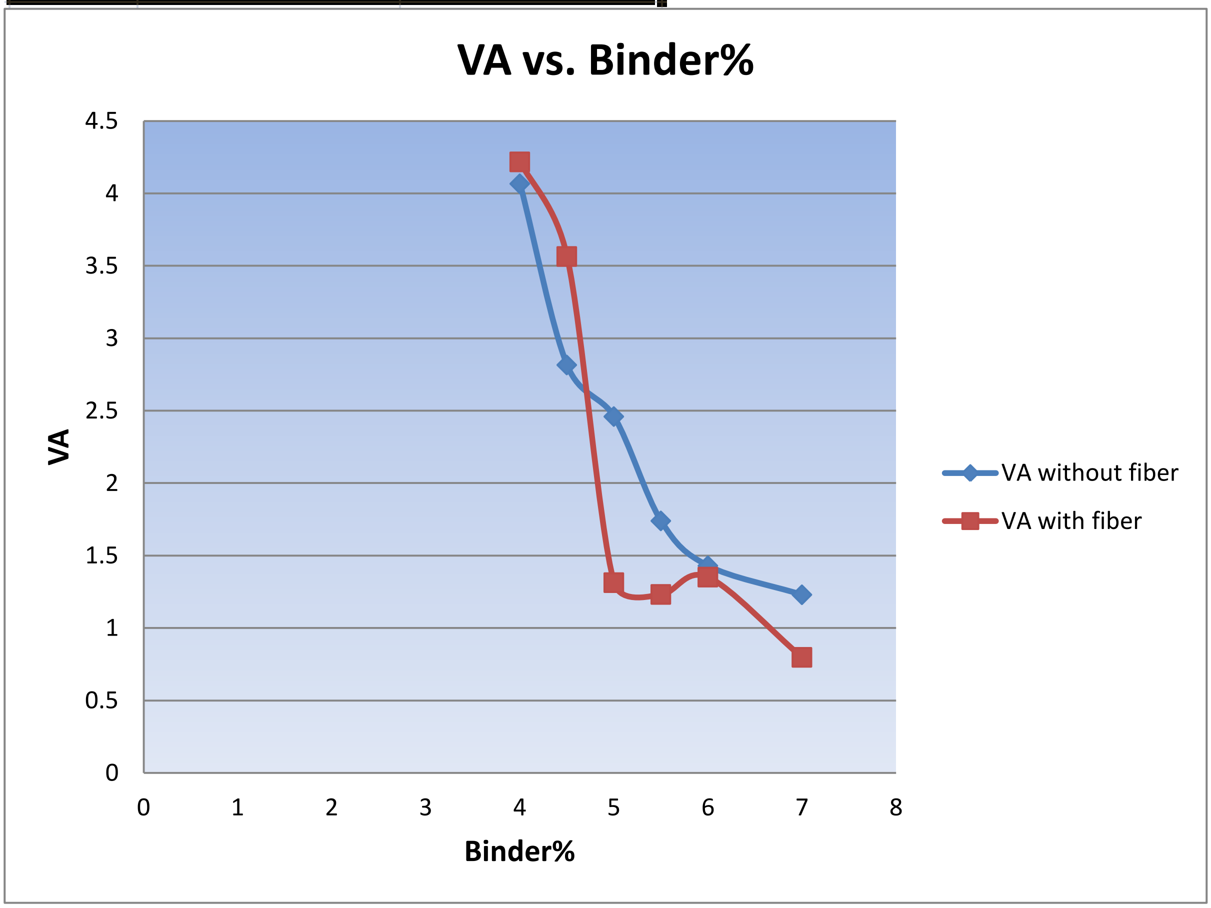

Figure 4.4 VA vs. Binder content%

4.3.5 VFB vs. bitumen content

Table 4.10 VFB vs. bitumen content

Binder%	VFB without fiber	VFB with fiber
4	69.89	67.69
4.5	78.72	72.94
5	82.46	90.61
5.5	86.03	91.5
6	90.44	91.36
7	93.93	95.15

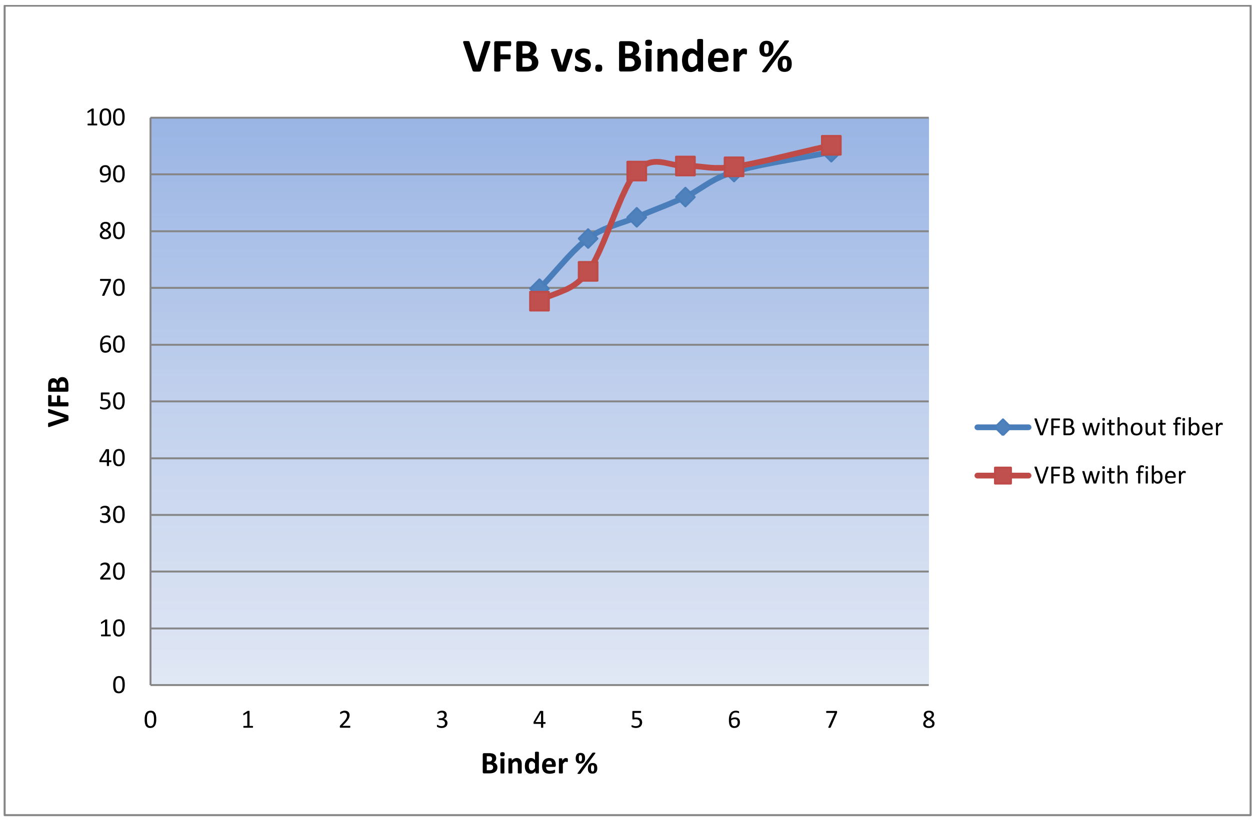

Figure 4.5 VFB vs. Binder content%

4.4 OPTIMUM BINDER CONTENT

The optimum bitumen content for the mix design is found out by taking the average bitumen content of three Marshall Properties. These are:

- Bitumen content at maximum stability
- Bitumen content at maximum unit weight
- Bitumen percentage corresponding to 4% air voids.

The method suggested above may not be suitable in SMA mixes due to its high coarse aggregate percentage. Hence we followed the Morth and IRC SP79,2008 specifications to find the optimum binder content which decides the OBC value based on 4 % air voids. Here we obtained the OBC with respect to 4%air voids. Hence the optimum binder was obtained as 4.2 %

- **Marshall Properties at OBC**
  Table 4.11 for Marshall Properties at OBC

Stability(Kn)	Flow(mm)	VMA	VA	VFB
7.25	2.64	13.37	4	68.03

4.5 DRAINDOWN CHARACTERISTICS

The results of this wire basket drain down test is given below .

Table 4.12 Draindown by wire basket method

Mass of empty wire basket A(gm)	Mass of wire basket plus sample B(gm)	Mass of empty catch plate C(gm)	Mass of catch plate plus drained material D(gm)	Draindown %
251.1	1452.5	424.2	424.30	0.008

4.6 STATIC INDIRECT TEST RESULTS

Table 4.13 Static indirect test values

Temperature	D	H1	H2	H3	H4	avg H	Load	P	St(Kpa)
5	10	6.4	6.3	6.3	6.2	6.3	1092	32460.79	328.0189
	10	6	6.1	6.1	6.4	6.15	961	28566.69	295.7093
10	10	6	6.2	6.2	6.3	6.175	623	18519.3	190.9272
	10	6.1	6.3	6.1	6.2	6.175	598	17776.15	183.2656
15	10	6.1	6.1	6	6.1	6.075	492	14625.19	153.2624
	10	6	6.2	6.3	5.9	6.1	524	15576.42	162.5617
20	10	5.9	5.9	5.8	6	5.9	427	12693	136.9596
	10	6	5.8	5.8	6.1	5.925	411	12217.39	131.2714
25	10	6	6	6.1	6.1	6.05	256	7609.856	80.07581
	10	6.3	5.8	5.8	6.2	6.025	288	8561.088	90.45908
30	10	5.9	5.9	6	6.1	5.975	148	4399.448	46.87492
	10	5.9	5.8	5.9	6.1	5.925	174	5172.324	55.57477
35	10	6	6	6.1	6	6.025	89	2645.614	27.95437
	10	6	6	6.1	5.9	6	106	3150.956	33.43269
40	10	6	6.1	6.1	5.8	6	64	1902.464	20.18578
	10	6.2	6	6	6.1	6.075	49	1456.574	15.26394

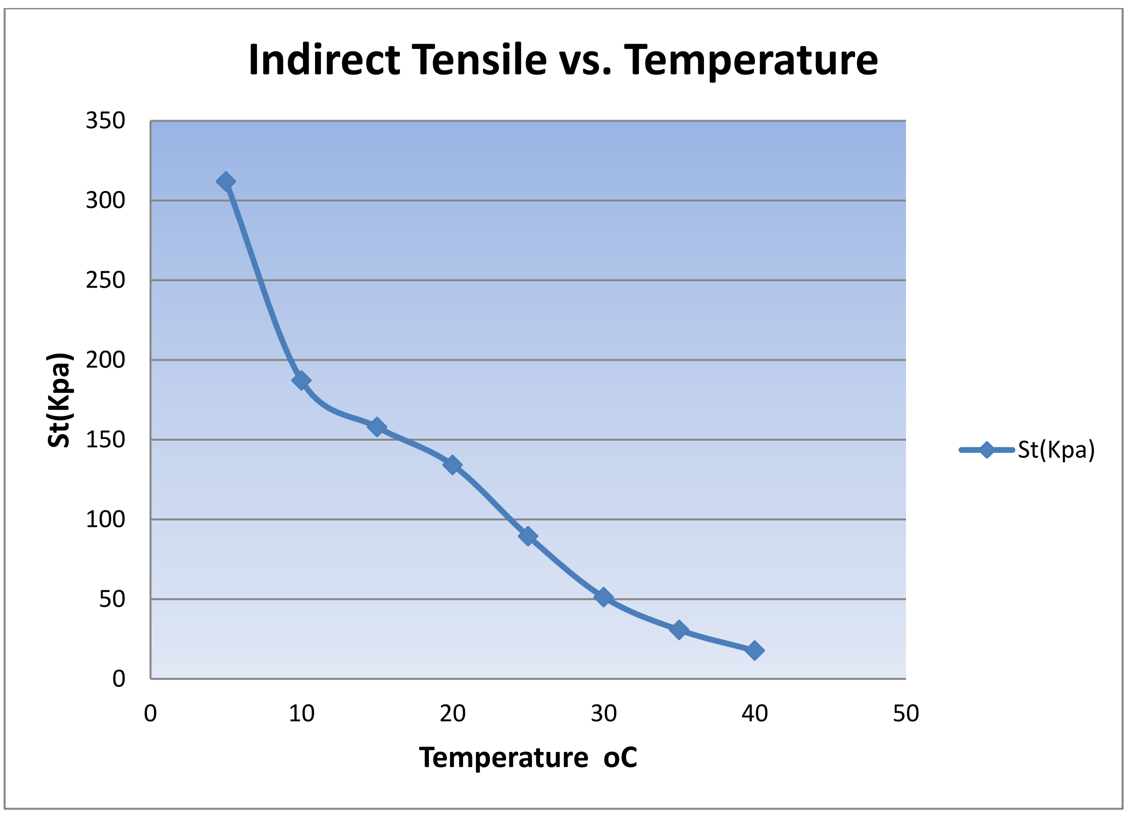

Figure 4.6 Static indirect test values vs Temperature 0C

The result of the indirect tensile test clearly indicates that the indirect tensile strength of the SMA sample decreases considerably with increase in temperature. At low temperature the tensile strength is very high but it reduces significantly with increase in temperature. This may be attribute to the fact that at lower temperature the binder becomes very stiff thus increasing the binding ability considerably, but at higher temperature the bitumen softens, loosens its binding ability , thus attributing to the loss of its tensile strength .

CHAPTER 5
INTERPRETATION OF RESULTS

5.1 INTERPRETATION OF RESULTS

- The SMA samples were prepared using varying bitumen content of 4%, 4.5%, 5%, 5.5%, 6%, and 7%. This was done to find out the effect of increasing bitumen content on the stability value. This plot also helps us to find the Optimum binder content for this mix. The plot below indicates that the stability value increases initially with increase in bitumen content but then decreases gradually. This can be attributed to the fact that with initial increase in bitumen content, the aggregate bitumen bond gradually gets stronger, but with further increase in the bitumen content, the applied load is transmitted as hydrostatic pressure, keeping the fraction across the contact points of aggregates immobilized. This makes the mix weak against plastic deformation and the stability falls.

  The same principle applies to mix with fibers, but this mix shows higher stability value at the same binder content than the mix without fibers. This can be attributed to the fact that , the fibers in the mixes act as stabilizers which not only fills up the voids in the sample but also reduces the drain down significantly, thus holding up the binder in the mix. The addition of fibers also provides homogeneity to the mix.

  Here in our result the stability results are higher for samples with fibers except for 4.5% which may be due to improper mixing .

- Flow is the deformation undergone by the specimen at the maximum load where failure occurs. The flow value increases with the increase in the bitumen content both the mixes with and without fibers .The increase is slow initially, but later the rate increases with the increase in the bitumen content.The flow value of mixes with fibers is more than that without fibers initially, This may be due to the reason that , at lower bitumen content the fibers fills up the voids effectively contributing to the homogeneity and thus providing the stability required to resist any deformation under load . But as the bitumen content increases the this homogeneity is lost , due to which the binder property dominates which makes the fibers to form lumps , reducing stability and increasing deformation under load .
- The VMA value, for a given aggregate should theoretically remain constant. However, in this case, it is sometimes observed that, at low bitumen content, VMA slowly decreases with the increase in bitumen content, then remains constant over a range, and finally increases at high bitumen content. The initial fall in VMA value is due to the re-orientation of the aggregates in the presence of bitumen. At very high bitumen content, due to a thicker bitumen film, the aggregates slightly moves apart resulting in an increase in VMA.

  The VMA values are quite similar in both the mix with and without fiber , but at larger bitumen content of 6%, VMA of mix with fiber is slight more , which can be attributed to the fact that at more bitumen content the fibers will form lump thus causing the further movement of aggregates apart increasing the VMA .

- The Air Voids (VA) decreases with increase in the bitumen content because with increase in bitumen content it goes on filling the air voids progressively.

  The VA of mix with fiber is much less than that without fiber. This is because the fiber already filled up some portion of air voids (VA) which further decreases as the bitumen goes on filling the air voids with increase in bitumen content.At 6% binder the VA values for sample with fiber are quite more than that without fiber which may be due to improper mixing .

- The Voids Filled Bitumen (VFB) is expressed basically as a fraction of VMA. . The VFB of a mix generally increases with the increase in the bitumen content. Here in our result too, we can clearly observe that VFB increases since increase in bitumen content causes more and more bitumen to fill the voids present in the mix as well as that inside the aggregates causing the overall increase in the bitumen inside the voids or VFB.

- The draindown remains to be one of the most important problems associated with SMA due to its high bitumen content .To counter this fibers as stabilizers are generally used . Here the draindown tests was carried out to compare the draindown characteristic s of samples with and without fibers at OBC .Three different percentages of fibers were used namely 0.2%, 0.3% and 0.4%.

  It was found out that with the use of fibers no drain down was obtained. Hence we can easily observe that use of fibers significantly reduce the drain down in a SMA Mix.

- The result of the indirect tensile test clearly indicates that the indirect tensile strength of the SMA sample decreases considerably with increase in temperature. At low temperature the tensile strength is very high but it reduces significantly with increase in temperature. This may be attribute to the fact that at lower temperature the binder becomes very stiff thus increasing the binding ability considerably, but at higher temperature the bitumen softens, loosens its binding ability , thus attributing to the loss of its tensile strength .The results are very high in case of 5^0C and very less for 40^0C

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